NBSI

Investigation of the Corrosion of Aluminum Standing-Seam Roofing at an Army Facility

Robert G. Mathey

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Gaithersburg, MD 20899

June 1986

Prepared for:

U.S. Army Corps of Engineers
Construction Engineering Research Laboratory
P.O. Box 4005
Champaign, IL 61820

and

Defense Logistics Agency
Installations Division
eron Station
andria, VA 22314

NBSIR 86-3387

INVESTIGATION OF THE CORROSION OF ALUMINUM STANDING-SEAM ROOFING AT AN ARMY FACILITY

Robert G. Mathey

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Gaithersburg, MD 20899

June 1986

Prepared for:
U.S. Army Corps of Engineers
Construction Engineering Research Laboratory
P.O. Box 4005
Champaign, IL 61820

and

Defense Logistics Agency
Installations Division
Cameron Station
Alexandria, VA 22314

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

ABSTRACT

An investigation was conducted to determine the extent of corrosion of an aluminum standing-seam roofing system exposed to weathering over a period of nearly three years. The aluminum roofing was installed on three large warehouses at an Army facility in Columbus, Ohio. A high performance elastomeric sealant was used in forming the standing seams of the roofing system. The roof slope, about 5 percent, was less than that usually recommended for unsoldered standing-seam roofing. The roofs were located in a region having a high level of acid rain.

In this preliminary study, small scale samples of the same material as the aluminum roofing were exposed on a rack mounted on the roof of one of the warehouses. The extent of corrosion of the roofing system was determined from measurements of mass and observations of the exposed small scale aluminum roofing samples. The change in mass of the exposed samples was compared to that of the control samples. The average rate of mass loss was calculated to be 0.038 $mg/dm^2 \cdot day$. Low power microscopic observations to determine the surface condition of the exposed samples after nearly three years exposure indicated a loss of gloss, an increase in surface roughness, and many small dark spots. At the dark spots, which were thought to be incipient corrosion, there was essentially no pitting.

Keywords: Aluminum roofing; corrosion; outdoor exposure; roofing; weathering

1. INTRODUCTION

1.1 Background

In July 1981, the Defense Logistics Agency (DLA) requested that the National Bureau of Standards (NBS) and the U.S. Army Construction Engineering Research Laboratory (CERL) provide technical assistance for a project involving the installation of aluminum standing-seam roofing on three large warehouses at the Defense Construction Supply Center (DCSC) in Columbus, Ohio. Both NBS and CERL were given copies of the plans and specifications for review. At a preconstruction conference held at DCSC in October 1981, comments from both agencies and details regarding the aluminum roofing systems were discussed.

Aluminum standing-seam roofing was specified to replace built-up bituminous roofing on the three warehouses which were each about 160 ft (48.8 m) wide and 1541 ft (470 m) long. Firewalls divided the roof into approximately 11 equal sections, each about 138 ft (42 m) long. The centrally located ridge of the roof extended the length of the building. The roof slope from ridge to eaves was about 5/8 in. per foot (50 mm/m). The aluminum panels used in the roofing system were 1 ft (305 mm) wide, 0.032 in (0.81 mm) thick, and 80 ft (24 m) long. They were rolled-formed with a 2-1/2 in. (64 mm) high rib on each side and two low profile equally spaced intermediate ribs. A strip type sealant was used in forming the standing seam which joined two panels together. The purpose of the sealant was to make the seam watertight. Construction of the aluminum standing-seam roofing at DCSC is described in CERL interim report M-336 [1]*.

---

* Numbers in brackets indicate references listed in Section 5.

One concern with the aluminum roofing system was the relatively low slope of the roof. The Department of Defense Manual on Maintenance and Repair of Roofs states that unsoldered standing-seam roofing should be used with slopes of 3 in. per foot (250 mm/m) or geater [2]. In addition, the standing-seam method for metal (unsoldered seams) roofing illustrated in the Architectural Sheet Metal Manual [3] is recommended for roofs having a slope of 3 in. per foot (250 mm/m) or greater. It is noted that the manufacturer of the aluminum roofing system recommended a minimum slope of 1/2 in. per foot (40 mm/m). Because of the relatively low slope of the aluminum roofs and also because Columbus, Ohio is located in an area having a high level of acid rain, DLA requested that NBS conduct a preliminary assessment of the performance of the aluminum roofing with regard to corrosion.

In carrying out the DLA aluminum roofing project, CERL had the overall responsibility to determine the behavior of the aluminum standing-seam roofing system over two annual cycles and to evaluate its capacity for long-term, trouble-free performance. The CERL report [1] documents the construction and instrumentation of the roof system for one of the three DCSC warehouses on which it was installed. Specific tasks assigned to CERL were to observe and monitor the construction of the roofing on the warehouses, to observe condition and performance of the roofing at periodic intervals, to measure deformation and movement of roof panels at appropriate locations, to measure temperatures of the metal and existing built-up roofing, and analyze and evaluate the results of the observations and measurements. The results of the analysis and evaluation will be documented by CERL in a final report.

1.2 OBJECTIVE AND SCOPE

The objective of this study was to conduct a preliminary assessment of the corrosion of the aluminum roofing system over a three year period using samples of the same roofing material that were exposed on a rack mounted on the roof of one of the warehouses. The change in mass of the exposed samples was measured and low power microscopic observations were conducted to determine the surface condition and extent of corrosion.

2. OUTDOOR EXPOSURE OF ALUMINUM ROOFING SAMPLES

2.1 DESCRIPTION AND PROPERTIES OF SAMPLES

Fourteen pieces, each about 16 in. (40 cm) long, of the 1 ft (30 cm) wide aluminum roofing panels were obtained and used to prepare samples for the exposure tests. These 16 in. (40 cm) long pieces were cut from the 80 ft (24 m) long panels at ventilator locations on the roof. Four samples for exposure tests were prepared from each of the 16 in. (40 cm) length of panel. The exposure samples were approximately 4 x 6 in. (10 x 15 cm) and had a low profile rib in the center that extended the length of the sample. Figures 1 and 2 show the sample configuration; figure 2 also shows a large area of the aluminum roofing system.

The aluminum panels has a nominal thickness of 0.032 in. (0.81 mm) and a textured finish described by the manufacturer as "stucco embossed." The average density of the aluminum roofing panels determined from tests of 42 specimens was 171.12 lb/ft^3 (2.74 g/cm^3). The manufacturer reported the panels to be corrosion resistant Alclad 3004* and they were furnished in mill finish.

2.2 EXPOSURE TESTS

Thirty samples were mounted on a rack and exposed at the same angle as the roofing. Figures 1 and 2 show the exposure rack mounted on the firewall of one of the warehouses at DCSC. The exposure rack faced west.

Each of the aluminum roofing samples was supported by six porcelain insulators. The method of support allowed for expansion and contraction of the samples

---

* This description was used to identify the aluminum roofing material, it does not represent an endorsement or disapproval by the National Bureau of Standards.

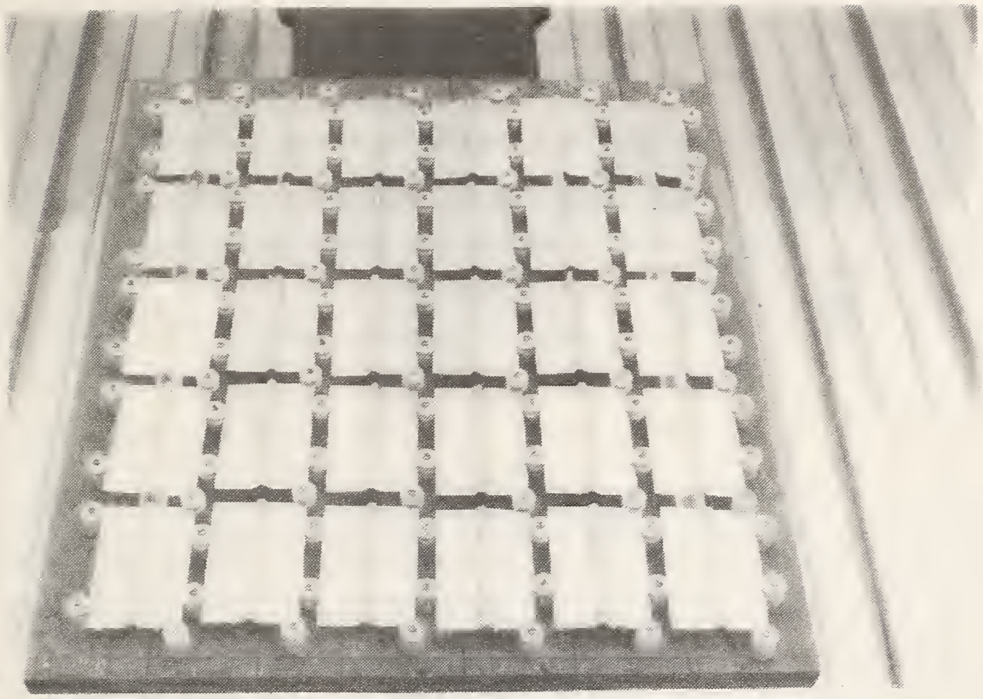

Figure 1. Aluminum roofing samples mounted on exposure test rack

Figure 2. Exposure test rack attached to fire wall between sections of roofing

without introducing stress in them. The samples were not in contact with any other material. Round slots in the insulators where the samples were supported (figure 2) allowed some movement of the samples and still maintained their adequate attachment. The insulators were held in place by screws attached to the wood rack. The distance between the samples and the wood rack was about 7/8 in. (22 mm).

The cleaning of the samples for their initial weighing and exposure consisted of soaking them in acetone for 10 to 30 minutes and rinsing them in ethyl alcohol. It is noted that this initial cleaning was found to be unsatisfactory. Because of this, the average rate of mass loss of the exposed samples was determined from a second exposure period. The samples for exposure were chemically cleaned before and after the second exposure period. Of the 56 samples included in the tests, 30 were selected for exposure and 26 were used as control samples. The control samples were stored in the laboratory in polyethylene bags and protected from light, moisture, and sources of contamination.

After 206 days of exposure (first exposure) the samples were returned to the laboratory, and both the exposed and control samples were weighed, chemically cleaned, following the methods in ASTM G1-81 [4], and weighed again. The exposure surfaces, or tops, of the samples were subjected to low power microscopic examination. The samples were then reinstalled on the exposure rack and exposed for 797 days (second exposure). After this second exposure they were returned to the laboratory and weighed, chemically cleaned, and weighed again. They were also examined visually and by using a light microscope at 10x.

3. LABORATORY MEASUREMENTS AND OBSERVATIONS

3.1 MASS LOSS

The samples were initially installed for exposure at DCSC on August 10, 1982, and removed for laboratory tests and observations on March 3, 1983 (first exposure). The samples were reinstalled on the exposure rack at DCSC on May 23, 1983, and removed for the second time for laboratory tests on August 1, 1985 (second exposure).

The samples were weighed before and after cleaning prior to the initial exposure and for each of the two times that they were returned to the laboratory for testing. The initial cleaning consisted of soaking them in acetone for 10 to 20 minutes and rinsing them in ethyl alcohol. When the samples were returned to the laboratory after exposure at DCSC they were chemically cleaned essentially as described by ASTM G1-81 for aluminum alloys [4]. The chemical cleaning of both the exposed and control samples was conducted as follows:

<u>step</u>

1.	Samples were dipped in the following mixture:	
	Chromic acid (CrO_3)	20 g
	Phosphoric acid (H_3PO_4, sp gr 1.69)	50 ml
	Water to make	1 liter
	Temperature of the mixture	80°C (176°F)
	Time in the mixture	6 to 7 minutes
2.	Rinse sample in distilled water	6 to 7 minutes
3.	Scrub specimens lightly with a bristle brush under running water	
4.	Rinse specimens in distilled water	6 to 7 minutes
5.	Place specimens in methyl alcohol	6 to 7 minutes

After cleaning and weighing the samples after their second exposure (May 23, 1983 to August 1, 1985) at DCSC, 4 exposed and 4 control samples were cleaned

again as described above and then weighed. The reason for this second cleaning of these 8 samples was to determine the effect of the cleaning on mass loss.

The loss of mass of the aluminum roofing samples after each of the two exposure periods is given in table 1. The average value of the mass of the control and exposed samples is given for the samples after the first period of exposure and chemical cleaning. It can be seen from the mass loss data in table 1 that there was considerably more loss of mass of the control specimens after the shorter, first exposure, period than for the longer, second exposure, period. This may possibly be due to the initial cleaning of the specimens (acetone and alcohol) not removing as much adhered material from the samples as compared to the chemical cleaning procedure. The estimate of mass loss due to exposure reported herein is therefore based on the second exposure period since the samples were chemically cleaned before and after this exposure period.

Table 1. Mass Loss of Aluminum Roofing Samples

Type of Sample	Mass of Samples After First Exposure 1/ (g)		Mass Loss After First Exposure 1/ (g)		Mass Loss After Second Exposure 2/ (g)	
	$\overline{X}$ 3/	σ 4/	$\overline{X}$ 3/	σ 4/	$\overline{X}$ 3/	σ 4/
Control	35.7280	0.4878	0.0055	0.0009	0.0012	0.0003
Exposed	35.9003	0.5554	0.0188	0.0035	0.0485	0.0091

1/ First exposure period was August 10, 1982 to March 28, 1983 (206 days).

2/ Second exposure period was May 28, 1983 to August 1, 1985 (797 days).

3/ Average value of 30 exposed and 26 control samples.

4/ Standard deviation.

The surface area of the 4 x 6 in. (10 x 15 cm) samples is estimated to be 25.14 in.^{2} (0.016 m^2), since the samples have a low profile rib that extends along the center of the longitudinal direction. The average effective width of the samples, including the rib, was determined to be 4.19 in. (10.6 cm) from measurements of six samples. Using data from the second exposure period ($\overline{X}$ = 0.0485 g) the average rate of mass loss was calculated to be 0.038 mg/dm^2•day.

It was noted earlier that after cleaning and weighing the samples after the second exposure, 4 exposed and 4 control samples were again chemically cleaned and weighed to determine the effect of cleaning on mass loss. There was essentially no change in mass of the control samples after the second chemical cleaning of the samples from the second exposure, however, for the exposed samples the mass loss averaged 0.0016 g.

3.2 MICROSCOPIC EXAMINATIONS

ASTM Standards G1-81 [4] and G48-76 [5] were considered in examining and determining the extent of corrosion. It can be seen from the photograph (figure 3) of a typical exposed and control sample, that the exposed sample on the left has less gloss and greater surface roughness than the control sample on the right. Also, it can be seen that the surface of the exposed sample contains many small dark spots. It is thought that these dark spots represent incipient corrosion. Photomicrographs (10x) of a portion of the surfaces of typical exposed and control samples after the second exposure are presented in figures 4 and 5, respectively. The dark spots on the exposed sample seen in figure 3 are shown in more detail in figure 4. At the dark spots (incipient corrosion) there was essentially no pitting. The total time of outdoor exposure at DCSC of the exposed samples was 33 months and 26 days.

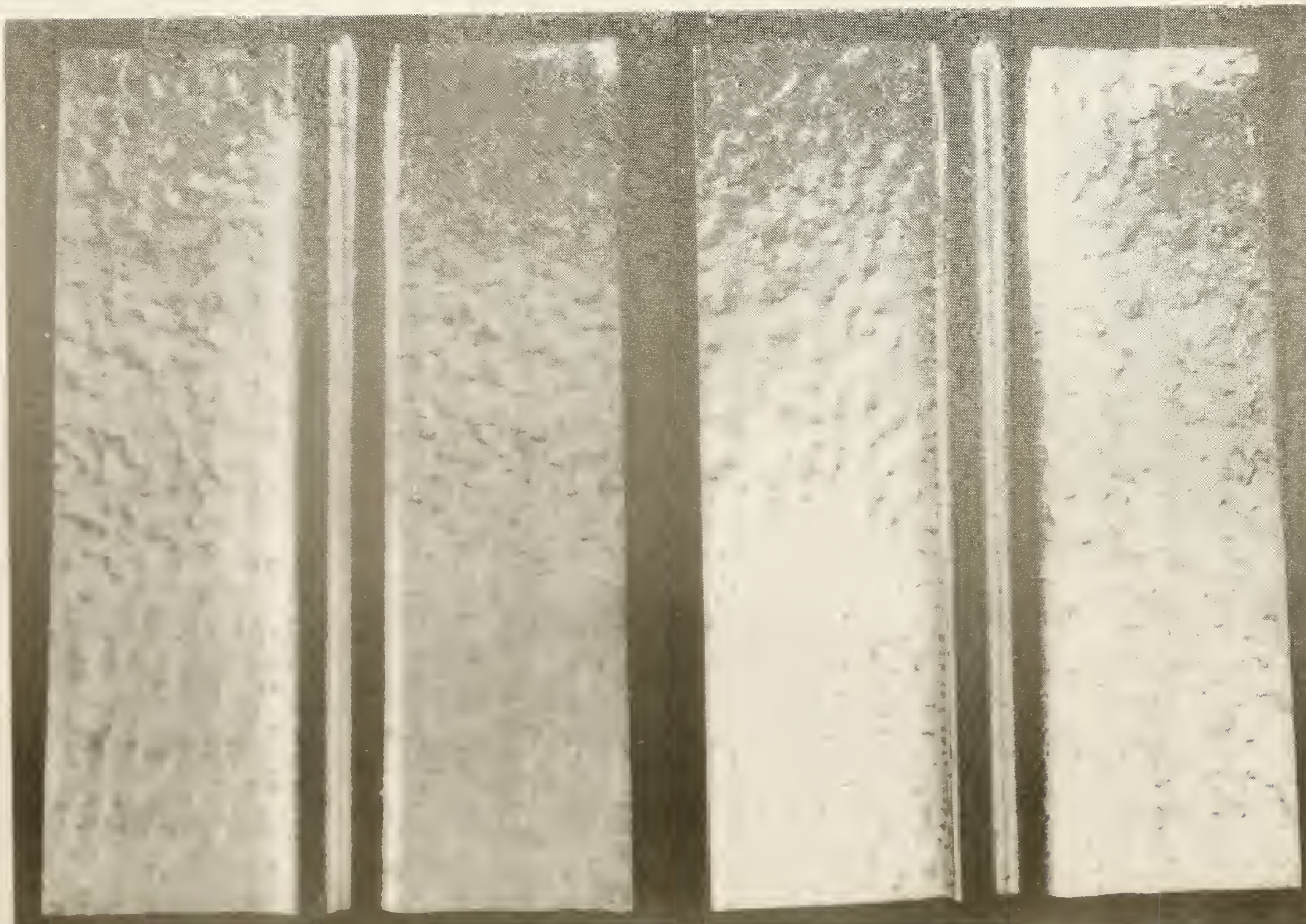

Figure 3. Exposed (left) and control (right) specimens

Figure 4. Photomicrograph (10x) of portion of surface area of exposed sample

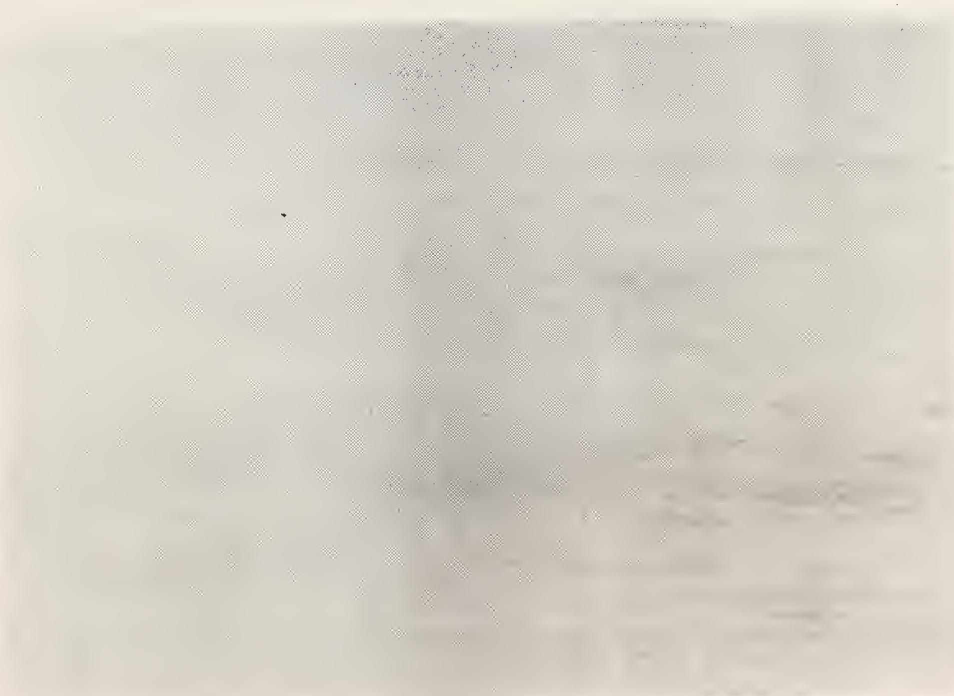

Figure 5. Photomicrograph (10x) of portion of surface area of control sample

4. SUMMARY

Aluminum roofing samples, 4 x 6 in. (10 x 15 cm) in size were exposed to outdoor weathering for nearly three years on a rack mounted on one of the roofs of the buildings at the Defense Construction Supply Center (DCSC) in Columbus, Ohio that were reroofed with an aluminum standing-seam roofing system. The samples were of the same material as the roofing system. The objective of the study was to conduct a preliminary assessment of the extent of corrosion of the aluminum roofing over a period of nearly three years. Changes in mass of the exposed samples were measured and the average rate of corrosion was calculated to be 0.038 $mg/dm^2 \cdot day$. Photographs and photomicrographs of exposed and control samples indicated a loss of gloss, increased surface roughness, and dark spots (incipient corrosion) at many locations on the surface due to the outdoor exposure. Observations of the surface of the exposed samples indicated that essentially no pitting occurred.

5. REFERENCES

1. Rosenfield, Myer J., "Construction of Aluminum Standing-Seam Roofing at an Army Facility," U.S. Army Corps of Engineers Construction Engineering Laboratory Interim Report M-336, November 1983.

2. "Facilities Engineering Maintenance and Repair of Roofs," Army TM 5-617, Navy NAVFAC MO-113, Air Force AFM 91-31, and Marine Corps MCO P11014.9, January 1974.

3. "Architectural Sheet Metal Manual," Sheet Metal and Air Conditioning Contractors National Association, Inc., Third Edition, Vienna, VA, 1979.

4. "Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens," ASTM Designation G1-81, 1982 Annual Book of ASTM Standards, Part 10, American Society for Testing and Materials, Philadelphia, PA.

5. "Standard Recommended Practice for Examination and Evaluation of Pitting Corrosion," ASTM Designation G48-76 (Reapproval 1980), 1981 Annual Book of ASTM Standards, Part 10, American Society for Testing and Materials, Philadelphia, PA.

6. ACKNOWLEDGMENTS

This study was sponsored by the U.S. Army Corps of Engineers Construction Engineering Research Laboratory and the Defense Logistics Agency. Special thanks and appreciation are expressed to Myer J. Rosenfield, CERL, Marvin U. Dubois, DLA, and William J. Smith, DCSC, for their assistance in carrying out this study.

NBS-114A (REV. 2-8C)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions)	1. PUBLICATION OR REPORT NO.	2. Performing Organ. Report No.	3. Publication Date
	NBSIR 86-3387	746	MAY 1986

4. TITLE AND SUBTITLE

Investigation of The Corrosion of Aluminum Standing-Seam Roofing at An Army Facility

5. AUTHOR(S)

Robert G. Mathey

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

8. Type of Report & Period Covered

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP)

U.S. Army Corps of Engineers
Construction Engineering Research Laboratory
P.O. Box 4005
Champaign, IL 61820

Defense Logistics Agency
Installations Division
Cameron Station
Alexandria, VA 22314

10. SUPPLEMENTARY NOTES

[ ] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

An investigation was conducted to determine the extent of corrosion of an aluminum standing-seam roofing system exposed to weathering over a period of nearly three years. The aluminum roofing was installed on three large warehouses at an Army facility in Columbus, Ohio. A high performance elastomeric sealant was used in forming the standing seams of the roofing system. The roof slope, about 5 percent, was less than that usually recommended for unsoldered standing-seam roofing. The roofs were located in a region having a high level of acid rain.

In this preliminary study small scale samples of the same material as the aluminum roofing were exposed on a rack mounted on the roof of one of the warehouses. The extent of corrosion of the roofing system was determined from measurements of mass and observations of the exposed small scale aluminum roofing samples. The change in mass of the exposed samples was compared to that of the control samples. The average rate of mass loss was calculated to be 0.038 mg/dm^2.day. Low power microscopic observations to determine the surface condition of the exposed samples after nearly three years exposure indicated a loss of gloss, an increase in surface roughness, and many small dark spots. At the dark spots, which were thought to be incipient corrosion, there was essentially no pitting.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Aluminum roofing; corrosion; outdoor exposure; roofing; weathering.

13. AVAILABILITY

[X] Unlimited
[ ] For Official Distribution. Do Not Release to NTIS
[ ] Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
[X] Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES

20

15. Price

$9.95